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A MENACE TO THE NEW YORK HARBOUR ENTRANCE.*

BY

LEWIS M. HAUPT, C.E.

> These restless surges eat away the shores
> Of earth's old continents; the fertile plain
> Welters in shallows, headlands crumble down,
> And the tide drifts the sea-sand in the streets
> Of the drowned city.
> WM. CULLEN BRYANT.

At the Buffalo meeting of this association, in 1886, the writer had the honour of submitting a paper on the "Problem of the New York Entrance," in which were set forth the peculiar physical conditions existing on the bar stretching from Sandy Hook to Coney Island, and suggesting a method of so modifying the ebb current passing out at Gedney's Channel as to increase the depth by natural erosion.

At that date the limiting depth in this, the deepest natural channel, was 23·3 feet at mean low water, which, with a mean tide of 4·8 feet, gave 28·1 feet at high stages, so that vessels drawing 27 feet have passed over it at extreme high water prior to improvement by dredging. In 1884 a report was submitted to Congress urging the enlargement of the channel to a width of 1,000 feet and depth of 30 feet by dredging, at an estimated cost of $970,000, as follows:

Improving Gedney's Channel for 30 ft., M.L.W.................	700,000 c. y., at 50 cts.
Improving Main Channel for 30 ft., M.L.W.....................	1,550,000 c. y., at 40 cts.

and it was expected that these channels would be "self-sustaining for many years." The Board of Engineers dissented from this

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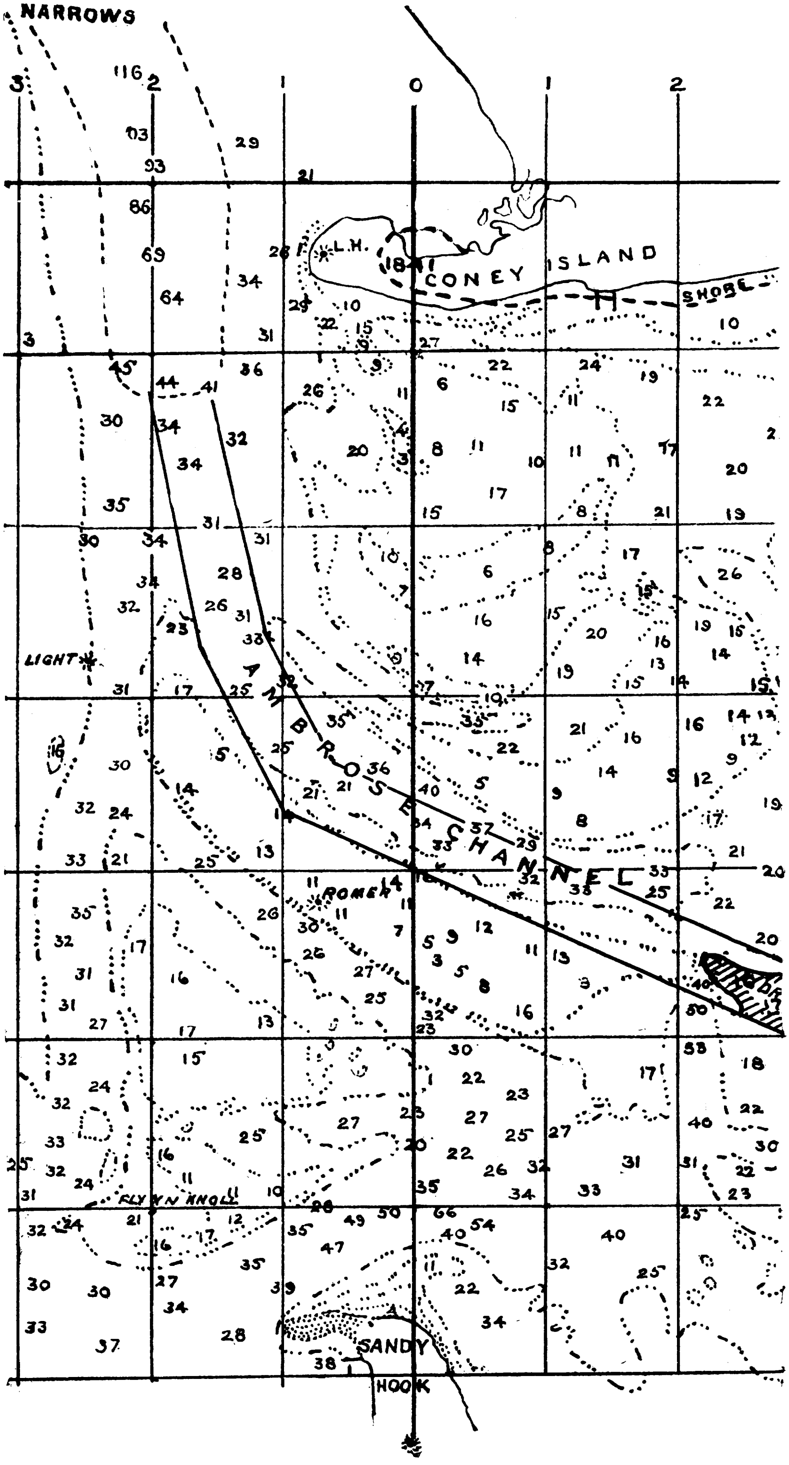
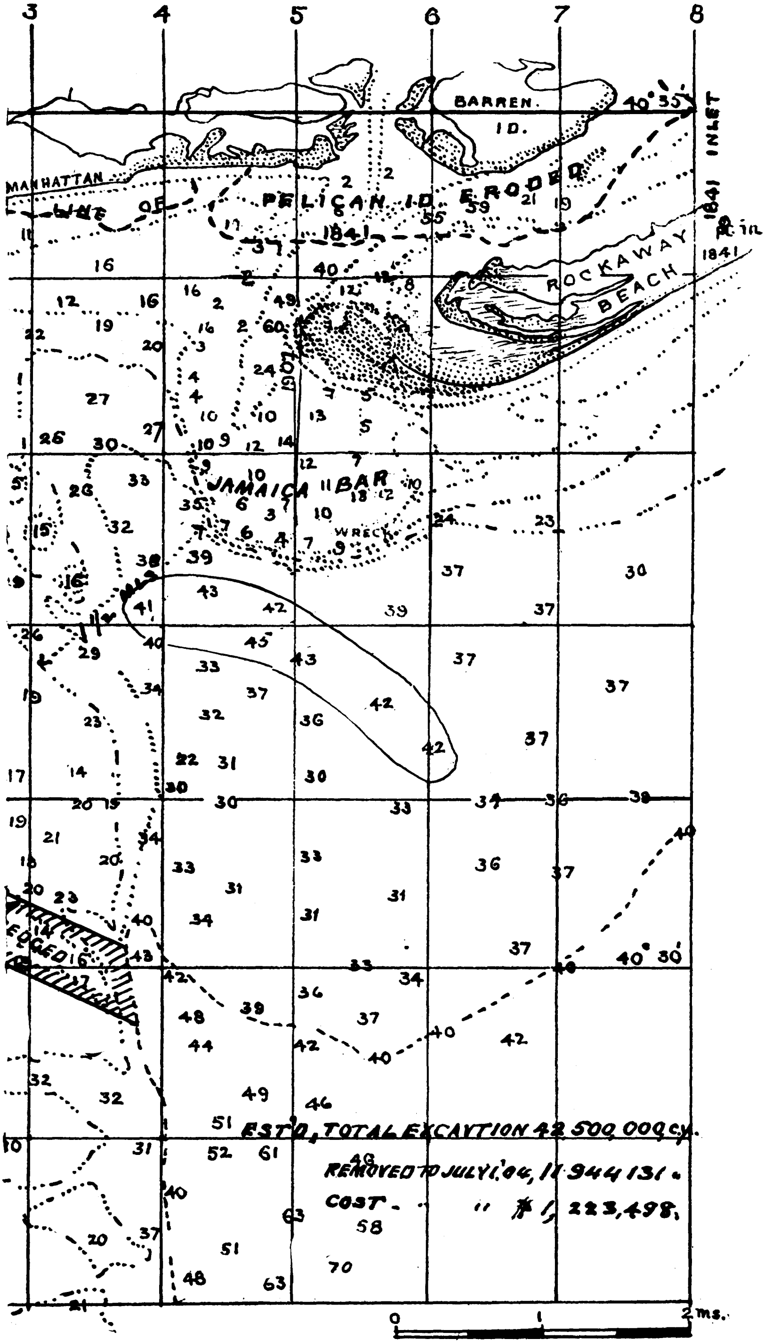
* A paper read before the annual meeting of the American Association for the Advancement of Science, held at Philadelphia, December 26–30, 1904. (*From advance sheets, by courtesy of the Franklin Institute.*)


NARROWS
3
2
1
0
1
2
L.H.
CONEY ISLAND
SHORE
LIGHT
AMBROSE CHANNEL
ROMER
FLYNN KNOLL
SANDY
HOOK


3
4
5
6
7
8
BARREN.
ID.
40°35'
1841 INLET
MANHATTAN
LINE OF PELICAN ID. ERODED
1841
ROCKAWAY BEACH
PT. IN 1841
JAMAICA BAR
WRECK
EDGED
40° 30'
ESTD. TOTAL EXCAVTION 42 500 000 c.y.
REMOVED TO JULY 1, '04, 11 944 131 .
COST . .. " $ 1, 223,498.
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view, however, and stated that it had "little expectation that anything more than temporary relief could be obtained from dredging on a bar exposed to the full force of the Atlantic, and hence cannot recommend that method for a permanent improvement." It therefore suggested a dike extending in a S.-S.E. direction from Coney Island at a cost of about $5,000,000 or $6,000,000. As this dike would have closed the Coney Island, Fourteen Foot, and East Channels, and would have reduced the tidal ingress, it was not built, and the method of dredging alone was adopted. The Board was fully cognizant of the fact that the sand was being moved from the adjacent shore of New Jersey and Long Island into the Lower Bay, as indicated by the spits at Sandy Hook and Coney Island; but the extent of this movement does not appear to have been very fully considered, although an important factor in the relative cost of creating and maintaining the channels. Especially is this true in view of the greater demands which modern vessels are exacting as to capacity and draught. Instead of 30 feet depth and 1,000 feet width, there are now required 40 feet and 2,000 feet, respectively.

It has also been found necessary to maintain the 30-foot channels by dredging at an annual charge of about $50,000, with no resulting increase of depths, so that in 1899 the project of opening a more direct channel *via* the East or Ambrose passage by dredging to a depth of 40 feet and a width of 2,000 feet was approved by Congress, provided the cost should not exceed $4,000,000 for the removal of the 42,500,000 cubic yards then in place.

Under the 30-foot projects the amount expended up to July 1, 1904, was $1,967,111.82, or about $1,000,000 more than the estimate even at the very high unit prices of 40 and 50 cents per yard.

Under the 40-foot project, to same date, there has been expended $1,223,498.52, and "11,944,131 cubic yards have been removed." From this statement it appears that the general cost has been 10¼ cents per yard in the Ambrose Channel.

In the report of the Board, composed of Generals J. C. Duane, Henry L. Abbott and C. B. Comstock, three of the most experienced members of the Corps of Engineers, it was stated that the movement of sand towards the New York entrance was manifested by the "form of Sandy Hook, a sand spit about 5 miles long, which has been slowly built during past ages by this northward movement of sand along the New Jersey shore. It appears to have reached a limiting length . . . and in the last 145 years its length has varied only about 2,700 feet. . . . An examination of the charts of Coney Island shows that its western end is moving westward as sand is moved to it, the motion of its 18-foot curve amounting to 800 feet between 1835 and 1881."

Unfortunately, this report does not appear to state the probable amount of material carried on to the bar by these two littoral movements. It is to set forth the great importance of providing for this menace to the entrance in the near future that some attention will be given to it in this paper. While physicists may be more especially interested in the vertical movements of the earth's crust, as suggested in the recent paper of Prof. J. W. Spencer on the submarine Great Cañon of the Hudson River, these internal forces do not appear to have sensibly affected the depths of the channels for commercial purposes within the range of modern records, so that the investigation of the volume and rate of drift wlll be confined to its horizontal littoral transportation.

For this purpose the British, Dutch, Swedish, and Spanish charts of the early explorers and settlers of the seventeenth century are found to be of no value, being apparently merely a collection of itinerary sketches of the general conformations of the coast, as seen from their vessels. Neither are movements which have passed their climaxes and reached a condition of equilibrium, or which are undergoing a transition under the new conditions which previous cycles may have imposed, as exemplified in the successive hooks which characterize the peninsula of Sandy Hook, where the third reflex spit is now forming.

Data.—An early colonial map of 1626 shows Sandy Hook under the name of Goodwin's Point, after whom the Lower Bay was also named, but it gives no geographical positions. The first charts of value for comparative study to which the writer has had access are those in the American Atlas, published by Wm. Faden, Charing Cross, London, in 1779, and collated by British officers during the Revolution. One of these, by Lieutenant Bernard Ratzer, of the Sixtieth Regiment, drawn from a survey of 1769, shows the New York Bay and Long Island on a scale of 6.6 miles to an inch. Another, being a detailed survey of the Hudson River and its mouth, published October 1, 1776, is on a scale of 4 miles to an inch, and a third, by Claude Joseph Sauthier, representing the entire State in sections, scale about 5 miles to an inch, was published in 1779. These three have been reduced to the same scale of 5 miles to the inch and superimposed for comparison as to position of shore-lines. The discrepancies, smallness of scale, and uncertainty of dates are such as to render them of comparatively little value, but they show the progressive movements of the inlets to the bays on the south shore of Long Island and the opening and closing of the breach at the mouth of the Shrewsbury River, N. J. Also the beginning of the outer beach, now covering "Rockaway Neck" and Jamaica Bay, and threatening the New York bar. The State map of 1779 makes the distance from the Battery of New York City to Sandy Hook Light only 14 miles, instead of nearly 17 as given by the Coast Survey charts, thus discrediting its accuracy and confining this investigation to the later and absolutely reliable charts of the U. S. Coast and Geodetic Survey and those of the U. S. Corps of Engineers.

Co-ordinates.—As a basis of orientation the Sandy Hook Lighthouse is taken as the origin, since its co-ordinates are practically identical on the British and American charts.

The axes of reference are the meridian of the lighthouse and the parallel of 40° 20′ 35″ N. latitude. On this meridian and parallel therewith, cross-sections have been constructed from the Coast Survey charts of 1841 and 1901 by dividing the arc of latitude into minutes (or 4,620 feet intervals) and taking the sectional area of the water extending for a distance of 3 knots southward. The area thus covered extended about 7·5 knots east and 3 south, embracing the travelling bank in front of Jamaica Bay and reaching beyond the old inlet of 1841.

The gain or loss in the water cross-sections indicates the amount of erosion or deposit in the past sixty years; but it should be noted that this is merely the local resultant change, and that it by no means represents the total movement of drift. This latter quantity can best be ascertained only when it is finally impounded in the bight of some re-entrant having no internal tidal compartments. Along an open beach with numerous receptive inlets and a great bay at its terminus, all acting as pockets for sand, it is indeterminate, except by constructing an extensive groin to intercept it. Along an unbroken beach the volume of drift may be very large, yet the net changes, after its equilibrium is established, may be very small, or zero. When a breach occurs, however, the sand enters, and is precipitated on the inner bars and islands, until the inlet drifts past, and the bay or sound becomes closed to the littoral material, which then travels on to the next dump. The outer bar resulting from the effluent currents of the bay modifies to a great extent the action of the littoral forces by deflecting them in part around the submerged obstruction which they are constantly attacking on the windward side, from which the sand is eroded and carried by a circuitous path to the leeward slope. At the toe of this latter slope and along the beach front beyond the bar there is apt to be erosion from the eddy caused by the returning currents. These generalities are illustrated by the following tabular exhibit computed from the cross-sections of the Coast Survey charts of 1841–1901, with such intermediate sections as were necessary to locate the scarps and counterscarps of the channel at these dates, or after sixty years' interval. The sections are arranged from east to west, to follow the direction of the movement. Between Nos. 7½ and 10, inclusive, there has been an increase of the water section or scour, but auxiliary sections extending farther east to Rockaway Life-saving Station show no material change, unless it be a deepening beyond the five-fathom curve. Between the Jamaica and New York bars there has been a small amount of scour in the flood-tide channel under Coney Island, and a recession of the beaches, which is pronounced along Plumb and Pelican Islands. A submerged ridge has formed in this trough, which has reduced the depths from 28 to 15 feet—a loss of 13 feet.

COMPARATIVE MARINE CROSS-SECTIONS OF VICINITY OF JAMAICA INLET, EXTENDING FROM THE MERIDIAN OF SANDY HOOK LIGHT EASTWARD 46,200 FEET, 8.75 STATUTE MILES, AND SOUTHWARD FROM LATITUDE 40° 35′ N. THREE KNOTS. FULL INTERVAL = 4,620 FEET.

NO.	DATE 1841. SQ. FT.	DATE 1901. SQ. FT.	DECREASE. FILL — SQ. FT.	INCREASE. SCOUR +.	VOLUME. CUB. YDS. DEPOSITED.	REMARKS.
10	384,635	433,323	—	48,688	—	—
9	256,829	338,381	—	81,552	—	—
8	241,847	266,568	—	24,721	—	—
7½	172,842	253,177	—	80,335	—	Scarp of 1841.
7	323,775	227,616	96,159	—	2,079,000	Through inlet and bar of 1841.
6½	288,476	232,485	45,991	—	5,250,000	Counterscarp of 1841.
6	293,345	216,661	76,684	—	6,160,000	—
5½	320,123	189,883	130,240	—	8,840,000	Scarp of 1901 { Deposited outside, 182,580 Scour inside...... 52,340
5	329,861	202,055	127,806	—	11,300,000	Gorge of 1901.
4½	355,422	233,702	121,720	—	13,700,000	Counterscarp.
4	322,581	402,893	80,312	—	5,555,000	—
3	323,775	283,607	40,168	—	10,000,000	—
2	206,924	234,919	—	27,995	2,000,000	—
1	158,236	186,231	—	27,995	—	—
0	121,937	139,978	—	18,041	—	On Sandy Hook Meridian.
Av.	273,374	249,432	23,942		64,844,000	Deposited in 60 years ±.

The difference of the mean sections gives an average reduction of 23,942 square feet, or about 900 cubic yards per lineal foot, which for the total distance of 46,200 feet would give 693,000 yards per year as compared with the nearly 1,100,000 as included in the bar reach and representing its annual increment.

The bar proper covers a length along the beach of about 3½ miles and extends seaward nearly the same distance, while the direction of its movement has changed since passing Rockaway Station from west to nearly southwest, and this, if continued, will pass through the Light on the Romer Shoal and bisect the Ambrose Channel. It is now but 2½ miles distant from the 6-foot contour of the Jamaica bar to the 14-foot depth at the end of the new channel. There are no points between reaching to 40 feet excepting a small basin ½ mile wide, having one sounding as great as 46 feet, and as the Jamaica bar rolls up on the outer slope of the main ridge with its diminishing depth, the rate of progress will be more rapid and the distribution of material more extensive.

The table above shows the maximum reduction of the cross-section of the waterway at Station 5½ (the present scarp) to have been 130,240 square feet, which is greater than the entire area of the waterway for the 3 knots covered by the initial section at Station O, so that there is not space on the bar for this deposit without spreading to the southward and flowing into the channel, just as the spit at Sandy Hook is now changing its direction and moving to the westward as the ramparts of the sea encroach upon the gateways of the tide.

Rate of Approach.—Under these conditions the question naturally arises as to how soon this great increase in the volume of material may be expected to reach the bar, and it is one more readily answered than that of quantity, since a comparison of the authentic Coast Survey charts from 1841 furnishes evidence that the progression of the easterly spit of Jamaica Bay has been 2⅞ miles in sixty years, or at the annual average of 253 feet—that is, 1 mile in 20·86 years. If the British chart of 1776, made by Sauthier, be taken as reliable, the rate has been about 7 miles in 125 years, or 295 feet per annum. One mile in eighteen years, nearly.

As a further check under somewhat similar conditions of exposure and activity the charts for Fire Island show a westerly drift of 11,600 feet in 52 years, or 224 feet a year. The Board of Engineers of 1897, in reporting on the conditions at Aransas Pass, Tex., on the Gulf of Mexico, stated that "for many years it moved in a southerly direction. . . . The annual rate of movement from 1868 to 1878 was about 260 feet."

These few instances will serve to show that a movement of about 260 feet a year is not abnormal, and may be accepted as safe, so that the 40-foot basin should be crossed in about ten years, after which the rate should be more rapid in mounting the scarp of the outer bar. As it will require about ten years to remove the original material in place, in the Ambrose Channel, which is already reported to have filled from 3 to 7 feet, where work has been done, it will be seen that the problem assumes a serious aspect, and there would seem to be no question as to the futility of attempting to create, and especially to maintain, a channel by "dredging on a bar exposed to the full force of the Atlantic," which the Board of 1884 could not recommend for its permanent improvement. But this is not all; for, while the marine forces of the Long Island littoral are so rapidly storming the left flank of the enceinte, those of the New Jersey coast are likewise attempting to turn the right and rear. It is, therefore, necessary to reconnoitre in this direction to ascertain the force of the enemy and his line of approach.

Growth of Sandy Hook.—The encroachment of this peninsula of sand, extending northwardly across the entrance for a distance of five miles, has long been a subject of investigation and a cause of alarm, lest it ultimately close this portal to the harbour. The U. S. Coast Survey Commission made a special report on this subject in 1857, in which it said:

> The disastrous result of the continued growth of Sandy Hook into the main ship channel, its progress having been for the last century at the rate of nearly "a sixteenth of a mile in twelve years," needs no exaggeration to give it importance. . . . If its encroachments in the same direction were continued beyond certain limits, the destruction of the harbor might ensue.
>
> Within twenty years (1835–55) the point has grown to the northward 220 yards. It is altogether probable that the future progress of commerce will render the deepening of the bar a vital question.

The half century just closed has fully confirmed these predictions, and lends weight to the need of a more extended analysis of the rate and direction of the drift which is gradually throttling this mouth of the bay. The rates of growth above cited give an average of twenty-six feet per annum for the century, and 33 feet for the score of years, but the variations in the progress of the spit will be more clearly exhibited by the subjoined tabular statement, compiled from numerous charts, some of which are of doubtful authenticity, and hence of little weight. As the opening and closing of the mouth of the Shrewsbury River at the foot of the Hook is a factor in the travel of drift, an effort has been made to determine the dates when open. An old provincial map of New Jersey, published by Seller and Fisher in 1676, shows a small projection of $\frac{1}{10}$ of an inch in length on the site of Sandy Hook, connected with the mainland; but as there is no scale, it is valueless. A map of New York and Perth Amboy Harbours in 1733, drawn to scale and apparently made from surveys, is taken amongst the earliest reliable maps for this study. On this chart the Hook is but three miles long, which is apparently erroneous as compared with Lay's map of 1724. The depth of 19 fathoms in the Narrows and 3½ in the main Ship and Gedney's Channels are the same as those prior to the dredging, commenced under the project of 1884.

MOVEMENTS OF SANDY HOOK AND CONDITION OF SHREWSBURY INLET.

DATE (YEAR).	LENGTHS (MILES).	FEET.	AUTHORITY.	INLET CLOSED OR OPEN.	AVERAGE RATE PER ANNUM IN FEET.	REMARKS.
1724	4·00	21,120	Amos Lay.	Closed.	For 50 years to 1776 there seems to have been no advance.	Scale 7^m = 1″
1733	3·00*	15,840	Not stated.	"		" $3\frac{1}{3}^m$ = 1″
1769	3·96	20.909	Lt. Ratzer.	"		' 6⅔ = 1
1776	4·00	21,120	(Hudson River.)	"		" 4^m = 1″
1778	4·40	23,232	" Lord Howe."	Open.	1,056	" ¾ = 1″
1779	4·4	23,232	C. J. Sauthier.	"	0	" 5 = 1″
1782	4·5	23,760	Lt. J. Hills.	"	176	" $\frac{1}{10000}$
1819	4·53	23,918	Capt. LeConte.	Closed.	4	" "
1836	4·67	24,657	U. S. C. Survey.	Opened in 1835.	43	" "
1841	—	—	"	"	—	" "
1842	4·80	25,344	"	Closed.	114	" "
1844	4·83	25,520	"	—	88	" "
1848	4·83	25,520	"	Open.	0	" "
1850	4·80	25,344	"	Closed.	− 88	" "
1851	4·78	25.388	"	Open.	+ 44	" "
1855	4·77	25,335	"	Closed.	− 13	" "
1857	5·00	26,400	"	" †	+ 530	† Permanently by railroad.
1863	—	—	—	"	—	Severe storm cut away, making jetties and rip-rap necessary, 2,575 feet long.
1881	4·9	25,872	—	"	− 26	
1891	4·8	25,344	U. S. C. Survey.	Closed.	− 75	Scale $\frac{1}{40000}$

A glance at the rate-column shows some very eccentric features, and impresses the need of systematic records at stated periods as a basis for definite conclusions. It would appear that, for the half century from 1724 to 1776, the spit was in a condition of equilibrium (neglecting the survey of 1733). During Lord Howe's occupation a spit of sand nearly half a mile in length extended to the northwest, and the fast land soon followed it. Another cycle occurred between 1779 and 1848, a period of sixty-nine years, during which ·43 of a mile, or 2,288 feet, were reclaimed from the sea, giving an average progression of 33 feet per annum. Since 1848, whilst there has been fluctuation, there is no material advance upon the channel northwardly, but instead there has been a protrusion of a long spit of a half mile to the westward, forming the third cove on the inner face of the Hook.

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* Distance uncertain. † Six feet deep.

The revetment of the head of the Hook after the severe storm of 1863 checked the erosion to some extent.

In 1881 the nucleus of the westward movement was shown to have commenced. Taking the depth at 45 feet, with slopes of 1 on 12, this deposit to date would represent approximately 10,000,000 cubic yards, or about a half-million a year, which has been arrested under the lee of the Hook, notwithstanding the inner littoral current which prevails for eleven hours out of the twelve. This does not represent, by any means, the additional amount of sediment carried into the bay in suspension and deposited in its channels and on its bars. The annual dredging required to maintain the full dimensions of Gedney's Channel, especially on the south side of the cut, indicates the presence and source of this material.

This may be checked by the larger deposit made on the Hook proper between 1776 and 1857, when it advanced nearly a mile in length and expanded to a mean width of a mile. The uncertain element in this computation is the mean depth of the bed, but as there is always a deep-water reaction basin at the head of such spurs reaching to between 50 and 60 feet, it is safe to assume the depth of the fill at 15 yards. With these dimensions the yearly deposit has been 581,000 cubic yards on the fast land of the Hook, thus confirming within reasonable limits the probable annual deposit in this vicinity to be in round numbers 500,000 cubic yards. The northern mile of the Hook contains about 46,500,000 yards in place.

Unfortunately, the data contained in the above table furnish an uncertain basis from which to determine the age of Sandy Hook, but in the period of eighty-one years between 1776 and 1857 it apparently advanced one mile, or at the rate of about 65 feet per annum. To cover the entire five miles at this rate would require about four centuries, leading back to the date of the discovery of America. It is highly probable that the rate was much less at an earlier date, when the coast to the southward was indented with numerous inlets, which have nearly all been closed by the northward littoral drift and converted into fresh-water lakes. The only important openings to-day are those of Shark River and Manasquan, until Barnegat is reached, where the drift is to the southward.

From the foregoing statements it would appear that both flanks of the entrance are menaced by large deposits of sand in place, whilst the flood-tide is augmenting this volume by material carried in suspension, thus hastening the deterioration of this entrance by these encroaching banks.

THE GREYTOWN HARBOUR.

That this is no idle fancy will appear from a brief consideration of the physical conditions at the mouth of the San Juan del Norte at Greytown, Nicaragua, upon which so much stress has been laid in recent years. Here the trade-wind, rather than the tide, is the predominating element to drive the waves to the westward and extend the Hook in that direction, so that the excellent roadstead which existed in 1832 was completely sealed in 1865, during which period of thirty-two years the spit had advanced over a mile and a half, moving at an average rate of 291 feet each year.

A careful computation from comparative cross-sections of this cordon of sand, covering a period of some forty years, made by the writer on the spot in December, 1897, gave the annual deposit as 582,000 cubic yards during the latter part of the movement.

By a comparison of the survey of Commander Lull, of 1872, with that of Captain West, of 1865, covering a little more than seven years, after the lagoon had been formed, Prof. Henry Mitchell estimated the average yearly deposit on the sea slope of Punta Arenas to be 730,000 cubic yards. Here the coastal plain is characterized by five distinct lagoons—Ibo, Barco, Sucio, Shepherd's, and Greytown—having their axes nearly parallel and from 3,000 to 3,750 feet apart, all to leeward of the salient and within three miles of the coast, thus demonstrating the persistence of the forces and their cyclic results. The short pier of 1,000 feet, built by the Maritime Canal Company, arrested this drift and caused a general advance of the shore-line to windward for a distance of more than a mile. It also opened and maintained a channel into the lagoon until the groin filled up. This typical instance is cited to illustrate the gravity of the encroachments upon the New York bar where the aggregate deposits are more than twice as great, being concentrated from both the Long Island and New Jersey coasts, as from a funnel, upon the bar stretching from Coney Island to Sandy Hook.

Land Titles.—Aside from the physical, engineering, or commercial importance of this question there is the legal one of proprietorship. Stakes, pins, or landmarks driven into these travelling beaches do not hold them down, and the inaccuracies of the early colonial surveys and descriptions are so vague as to lead to great confusion. In a Supreme Court decision rendered in July last in favour of the town of Hempstead, Long Island, the defendant, based upon surveys several centuries old, the Court ruled "That old maps of the beach on Long Island are but slight evidence of the condition of the beach or the location of the inlets at a period fifty years earlier, even though correct at the time made. It is a fair presumption that the constant shifting in the various inlets of Rockaway Beach, on Long Island, shown to be going on at the present time, was going on in 1725." From this it appears that such a description as is contained in the deed of "A beach lying on the south side of the Island at a place called Rockaway" is not such as would convey title to a definite tract of land subject to the action of such physical forces. For the purpose of preserving to the rightful owner the full possession of his property, therefore, it becomes of importance to establish well-defined reference marks and to ascertain by frequent and systematic examinations the character and amount of the changes which are taking place as a basis for the best method of reclamation and protection to riparian owners, with correlative aid to commerce and marine industries.

The Remedy.—In view of the situation the preventive measures seem to be self-evident; yet thus far no permanent regulating works are contemplated which look to the modification of the tidal forces, either to diminish the rate of encroachments from the flood-driven sand-bars or to augment or localize the energy of the ebb scour, so that it is risking nothing to say that the Board of 1884 was correct in its judgment as to the inexpediency of attempting to meet the demands of commerce by dredging. If it were true then it is more so now, and yet it is quite possible so to control the ebb currents by a permanent training wall as to cause them to cut out and maintain by their own energy an ample channel across this bar. Such a structure would not obstruct nor close any of the existing channels, but would protect the Ambrose Channel from drift and would cost only about one-half the amount estimated for merely the preliminary dredging of the proposed channel. This should be supplemented by auxiliary works to impound the travelling sands in natural depositories, where they will become valuable instead of injurious, and prevent the ultimate formation of a new beach in front of Manhattan and Coney Island, which would then be on a bay a mile or more from the sea.

The details as to plans, dimensions, mode of construction, materials, and cost of these works belonging more properly to the subject of the Engineering Section, are consequently omitted from this paper, which is respectfully submitted for discussion, though with a consciousness of the deficiency and unreliability of the earlier data.